PAı ⊏NT COOPERATION TREAT .

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 22 March 2001 (22.03.01)	
International application No. PCT/AU00/00821	**Applicant's or agent's file reference** FP13043/CLC
International filing date (day/month/year) 07 July 2000 (07.07.00)	**Priority date** (day/month/year) 09 July 1999 (09.07.99)
Applicant CAMPBELL, Jonathan, Joseph et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   08 February 2001 (08.02.01)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer F. Baechler Telephone No.: (41-22) 338.83.38

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ ____________________

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only	
Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION		Applicant's or agent's file reference FP13043/CLC
International application No. PCT/AU00/00821	International filing date *(day/month/year)* 07 JULY 2000	(Earliest) Priority date *(day/month/year)* 09 JULY 1999
Title of invention A SYSTEM FOR MONITORING MECHANICAL WAVES FROM A MOVING MACHINE		

Box No. II APPLICANT(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*	Telephone No.:
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION Limestone Avenue CAMPBELL ACT 2612 AUSTRALIA	Facsimile No.: Teleprinter No.:
State *(that is, country)* of nationality: Australia	State *(that is, country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code andname of country.)*

CAMPBELL, Jonathan Joseph
2643 Moggill Road
PINJARA HILLS QLD 4069
AUSTRALIA

State *(that is, country)* of nationality: Australia	State *(that is, country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code andname of country.)*

LIU, Yi
2643 Moggill Road
PINJARA HILLS QLD 4069
AUSTRALIA

State *(that is, country)* of nationality: Australia	State *(that is, country)* of residence: Australia

[X] Further applicants are indicated on a continuation sheet

See Notes to the demand form

Sheet No 2

International application No
PCT/AU00/00821

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SHARP, Victor
2643 Moggill Road
PINJARA HILLS QLD 4069
AUSTRALIA

State *(that is, country)* of nationality: Australia	State *(that is, country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SPENCER, Steven John
2643 Moggill Road
PINJARA HILLS QLD 4069
AUSTRALIA

State *(that is, country)* of nationality: Australia	State *(that is, country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

WELLER, Keith Russell
2643 Moggill Road
PINJARA HILLS QLD 4069
AUSTRALIA

State *(that is, country)* of nationality: Australia	State *(that is, country)* of residence: Australia

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is [X] agent [ ] common representative

and [X] has been appointed earlier and represents the applicant(s) also for international preliminary examination

[ ] is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked

[ ] is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Griffith Hack
GPO Box 3125
Brisbane QLD 4001
AUSTRALIA

Telephone No.: 61 7 3221 7200

Facsimile No.: 61 7 3221 1245

Teleprinter No.:

[ ] **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination **to start on the basis of:**

[ ] the international application as originally filed

the description [ ] as originally filed
[ ] as amended under Article 34

the claims [ ] as originally filed
[ ] as amended under Article 19 (together with any accompanying statement)
[ ] as amended under Article 34

the drawings [ ] as originally filed
[ ] as amended under Article 34

2. [ ] The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. [ ] The applicant wishes the start of the international preliminary examination **to be postponed** until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English

[X] which is the language in which the international application was filed.
[ ] which is the language of a translation furnished for the purposes of international search.
[ ] which is the language of publication of the international application.
[ ] which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby elects all eligible States *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes **not to elect:**

International application No
PCT/AU00/00821

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

			For International Preliminary Examining Authority use only: received	not received
1.	translation of international application	: sheets	☐	☐
2.	amendments under Article 34	: sheets	☐	☐
3.	copy (or, where required, translation) of amendments under Article 19	: sheets	☐	☐
4.	copy (or, where required, translation) of statement under Article 19	: sheets	☐	☐
5.	letter	: sheets	☐	☐
6.	other *(specify)*	: sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. [X] fee calculation sheet
2. [ ] separate signed power of attorney
3. [ ] copy of general power of attorney; reference number, if any:
4. [ ] statement explaining lack of signature
5. [ ] nucleotide and or amino acid sequence listing in computer readable form
6. [ ] other *(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

Clifford Carew Registered Patent Attorney of Griffith Hack for and on behalf of the applicant
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION,
JONATHAN CAMPBELL, YI LIU, VICTOR SHARP, STEVEN SPENCER AND KEITH RUSSELL

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):
3. [ ] The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. [ ] The applicant has been informed accordingly.
4. [ ] The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.
5. [ ] Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

10/019307 14

REC'D 15 MAY 2001

WIPO PCT

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference fp13043	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. **PCT/AU00/00821**	International Filing Date *(day/month/year)* 7 July 2000	Priority Date *(day/month/year)* 9 July 1999
International Patent Classification (IPC) or national classification and IPC **Int. Cl.** ^{7} B02C 025/00		
Applicant COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheet(s).

3. This report contains indications relating to the following items:

I	☒	Basis of the report
II	☐	Priority
III	☐	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☐	Certain documents cited
VII	☐	Certain defects in the international application
VIII	☐	Certain observations on the international application

Date of submission of the demand	Date of completion of the report
8 February 2001	10 May 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **ASOKA DIAS-ABEYGUNAWARDENA** Telephone No. (02) 6283 2141

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/AU00/00821

I. Basis of the report

1. With regard to the **elements** of the international application:*

[X] the international application as originally filed.

[ ] the description, pages , as originally filed,
pages , filed with the demand,
pages , received on with the letter of

[ ] the claims, pages , as originally filed,
pages , as amended (together with any statement) under Article 19,
pages , filed with the demand,
pages , received on with the letter of

[ ] the drawings, pages , as originally filed,
pages , filed with the demand,
pages , received on with the letter of

[ ] the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, was on the basis of the sequence listing:

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [ ] The amendments have resulted in the cancellation of:

[ ] the description, pages
[ ] the claims, Nos.
[ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims **1-21**	**YES**
	Claims	**NO**
Inventive step (IS)	Claims **1-21**	**YES**
	Claims	**NO**
Industrial applicability (IA)	Claims **1-21**	**YES**
	Claims	**NO**

2. Citations and explanations (Rule 70.7)

NOVELTY(N):

Claims 1-21

US 3690570 A (ROOT WILLIAM EDWARD) 12 December 1972

DE 4215455 A (GOLDER FRANCE DE) 18 November 1993

Derwent Abstract Accession No. K. 1137E/30, Class P41, SU 869 809 A (KAZA POLY) 7 October 1981

Derwent Abstract Accession No. 85-235616/38, Class P41, SU 1146084 A (KRIV ORE MINING) 23 March 1985

None of the citations discloses all of the features of the above claims.

INVENTIVE STEP(IS):

Claims 1-21 : as above

0/019307

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference (if desired) (12 characters maximum) FP13043/CLC

Box No. I TITLE OF INVENTION

A SYSTEM FOR MONITORING MECHANICAL WAVES FROM A MOVING MACHINE

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL
RESEARCH ORGANISATION
Limestone Avenue
CAMPBELL ACT 2612
AUSTRALIA

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: Australia

State *(that is, country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

CAMPBELL Jonathan Joseph
2643 Moggill Road
PINJARA HILLS QLD 4069
AUSTRALIA

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Australia

State *(that is, country)* of residence: Australia

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Griffith Hack
G P O Box 3125
BRISBANE QLD 4000
AUSTRALIA

Telephone No. 07-32217200

Facsimile No 07-32211245

Teleprinter No

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

LIU, Yi
2643 Moggill Road
PINJARA HILLS,
QLD 4069
AUSTRALIA

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Australia

State *(that is, country)* of residence: Australia

This person is applicant for the purposes of:

- [ ] all designated States
- [ ] all designated States except the United States of America
- [x] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

SHARP, Victor
2643 Moggill Road
PINJARA HILLS
QLD 4069
AUSTRALIA

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Australia

State *(that is, country)* of residence: Australia

This person is applicant for the purposes of:

- [ ] all designated States
- [ ] all designated States except the United States of America
- [x] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

SPENCER, Steven John
2643 Moggill Road
PINJARA HILLS
QLD 4069
AUSTRALIA

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Australia

State *(that is, country)* of residence: Australia

This person is applicant for the purposes of:

- [ ] all designated States
- [ ] all designated States except the United States of America
- [x] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

WELLER, Keith Russell
2643 Moggill Road
PINJARA HILLS
QLD 4069
AUSTRALIA

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Australia

State *(that is, country)* of residence: Australia

This person is applicant for the purposes of:

- [ ] all designated States
- [ ] all designated States except the United States of America
- [x] the United States of America only
- [ ] the States indicated in the Supplemental Box

- [ ] Further applicants and/or (further) inventors are indicated on another continuation sheet

Box No. VI PRIORITY CLAIM

☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (*day/month/year*)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 9/7/99 ~~9th July 1999~~	PQ1524	Australia		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (*only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office*) identified above as item(s) (1)

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) (*if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used*): ISA /	**Request to use results of earlier search; reference to that search** (*if an earlier search has been carried out by or requested from the International Searching Authority*): Date (*day/month/year*) Number Country (*or regional Office*)

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	: 4
description (excluding sequence listing part)	: 31
claims	: 4
abstract	: 1
drawings	: 10
sequence listing part of description	:
Total number of sheets	: 50

This international application is **accompanied by** the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other (*specify*):

Figure of the drawings which should accompany the abstract:

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Clifford Carew Registered Patent Attorney of Griffith Hack for and on behalf of the applicant, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION, Jonathan Campbell, Yi Liu, Victor Sharp, Steven Spencer, Keith Russel

For receiving Office use only

1. Date of actual receipt of the purported international application:	2. Drawings: ☐ received. ☐ not received
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:	
4. Date of timely receipt of the required corrections under PCT Article 11(2):	
5. International Searching Authority (if two or more are competent): ISA /	6. ☐ Transmittal of search copy delayed until search fee is paid

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes at least one must be marked)*:

Regional Patent

[x] AP **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ United Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

[x] EA **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

[x] EP **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

[x] OA **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*

[x] AE United Arab Emirates
[x] AL Albania
[x] AM Armenia
[x] AT Austria
[x] AU Australia
[x] AZ Azerbaijan
[x] BA Bosnia and Herzegovina
[x] BB Barbados
[x] BG Bulgaria
[x] BR Brazil
[x] BY Belarus
[x] CA Canada
[x] CH and LI Switzerland and Liechtenstein
[x] CN China
[x] CR Costa Rica
[x] CU Cuba
[x] CZ Czech Republic
[x] DE Germany
[x] DK Denmark
[x] DM Dominica
[x] EE Estonia
[x] ES Spain
[x] FI Finland
[x] GB United Kingdom
[x] GD Grenada
[x] GE Georgia
[x] GH Ghana
[x] GM Gambia
[x] HR Croatia
[x] HU Hungary
[x] ID Indonesia
[x] IL Israel
[x] IN India
[x] IS Iceland
[x] JP Japan
[x] KE Kenya
[x] KG Kyrgyzstan
[x] KP Democratic People's Republic of Korea
[x] KR Republic of Korea
[x] KZ Kazakhstan
[x] LC Saint Lucia
[x] LK Sri Lanka
[x] LR Liberia
[x] LS Lesotho
[x] LT Lithuania
[x] LU Luxembourg
[x] LV Latvia
[x] MA Morocco
[x] MD Republic of Moldova
[x] MG Madagascar
[x] MK The former Yugoslav Republic of Macedonia
[x] MN Mongolia
[x] MW Malawi
[x] MX Mexico
[x] NO Norway
[x] NZ New Zealand
[x] PL Poland
[x] PT Portugal
[x] RO Romania
[x] RU Russian Federation
[x] SD Sudan
[x] SE Sweden
[x] SG Singapore
[x] SI Slovenia
[x] SK Slovakia
[x] SL Sierra Leone
[x] TJ Tajikistan
[x] TM Turkmenistan
[x] TR Turkey
[x] TT Trinidad and Tobago
[x] TZ United Republic of Tanzania
[x] UA Ukraine
[x] UG Uganda
[x] US United States of America
[x] UZ Uzbekistan
[x] VN Viet Nam
[x] YU Yugoslavia
[x] ZA South Africa
[x] ZW Zimbabwe

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

[x] DZ Algeria
[x] AG Antigua and Barbuda

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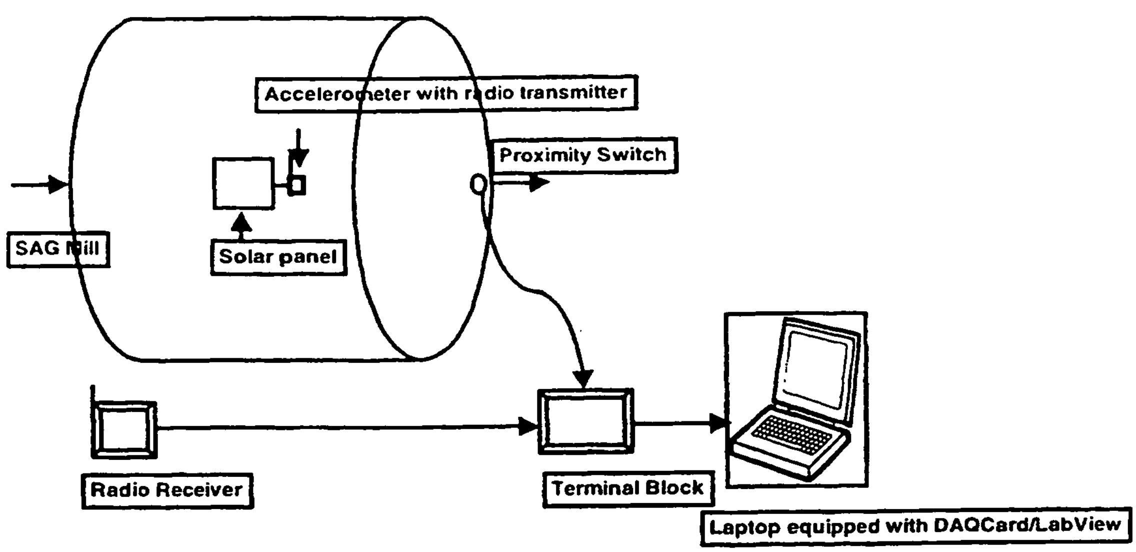
(54) Title: A SYSTEM FOR MONITORING MECHANICAL WAVES FROM A MOVING MACHINE



(57) Abstract: A system for monitoring mechanical waves from a machine which in operation has moving particulate matter therein, the system including at least one sensor located on the machine at a location away from the central axis of the machine, the sensors being for sensing acoustic waves and including a transmitter for transmitting signals representing the sensed mechanical waves to a receiver at a location remote from the sensor(s), a data processor connected to the receiver for receiving signals from the receiver which signals represent the mechanical waves and processing the signals to produce output signals for display on a display means, wherein the output signals for display represent one or more parameters indicative of mechanical waves emitted from the machine over a predetermined period of time.

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A SYSTEM FOR MONITORING MECHANICAL WAVES FROM A MOVING MACHINE

Field of the Invention

This invention relates to the monitoring and analysis of surface vibration waves generated by the operation of material processing equipment. 'The invention is of particular application to the non-intrusive monitoring and control of mineral processing equipment, such as tumbling mills, where the equipment component being monitored is in motion. The invention also has application to equipment with stationary components but moving mineral particles or pulp flows, such as crushers and hydrocyclones. The invention was initially developed for condition monitoring and process control of Semi-Autogenous Grinding (SAG) mills.

Background of the Invention

Acoustic emissions and surface vibrations monitoring, have previously been used to investigate and control the performance of mineral processing unit operations. Control of power draft in autogenous grinding (AG) mills and SAG mills has traditionally been via load cells estimating the charge mass. However, acoustic emissions from dual microphone systems have been used to monitor the changing level of impact of the charge on an AG mill shell. A pair of microphones were mounted at approximately 30° from the bottom and 30° from the centre line of the mill. The position of the microphones was such that the upper unit was above the normal level of charge impact on the liner while the lower unit was below the same. If the load level rises in the mill, the point of impact moves toward the upper microphone and away from the lower. If the load level drops, the converse applies. Therefore changes in load level are registered by variation in the comparative sound intensity at the two microphones. The resulting estimate of the load volume is correlated with the power draft and used to control the feed rate in order to maintain optimal milling conditions and maximum

power draft. It was shown that microphone signals are much more sensitive to load change than the load cell. However, the method is crude in that it uses sound intensity at only two fixed points outside the mill. The intensity of sound at these two positions may be considerably influenced by events both outside the mill and at a variety of locations within the mill. The technique therefore only permits qualitative investigation of the state of the charge inside the mill.

Acoustic emissions are also known to be indicators of pulp density and viscosity. The dual microphone study of AG mill acoustic emissions showed that the sound intensity emanating from the charge region (lower microphone) was correlated with the pulp density. The lower microphone sound intensity was used to control water addition rate. Low pulp density was thought to result in higher transmission of noise and increased media/media and media/liner collision events. Meanwhile at higher pulp density grinding action was thought to be inhibited by the increased pulp viscosity, reflected in lower noise intensity. Estimation of effective pulp density and viscosity via the magnitude of acoustic emissions has also been achieved for laboratory batch ball mills. Results suggest that changes in mill noise can be used to identify the pulp rheological regime and potentially used to optimise grinding efficiency. Mill sound noise has also been shown to indicate charge size distribution, ore breakage rates, and ore character in batch ball mills (Watson, 1985; Watson and Morrison, 1985).

Acoustic emissions monitoring has also been used to analyse hydrocyclone performance. A shear structure piezoelectric type acoustic sensor was mounted halfway along the conical section of a 5" hydrocyclone body. The digitised signal was sampled at 2000 Hz and a Fast Fourier Transform (FFT) algorithm used to derive the Power Spectral Density function (PSD) for analysis of acoustic emission characteristics in the frequency domain. Features of

acoustic emissions were analysed for varying feed solids concentrations and pressure. Results indicated significant spectral features in the frequency range from DC to about 50 Hz and between 30 and 45 Hz. The height of these spectral features was sensitive to operating conditions. It was conjectured that the spectral structure is related to features of the hydrodynamics inside the hydrocyclone local to the sensor. A stepwise regression analysis technique was used to derive linear relationships between the operating parameters of the cyclone and the spectral and statistical characteristics of the acoustic emissions. The signal measures used in this analysis were for the time domain maxima, mean, standard deviation, rootmean-square, skewness and kurtosis, and for the frequency domain the first 52 spectral components of the PSI). The model was then used for reasonable predictions of hydrocyclone feed pressure, solids concentration, mass and volume flow rates and underflow concentration. This investigation showed that non-invasive acoustic emission measurement coupled with multivariate statistical analysis techniques are a useful tool for monitoring the bulk characteristics of both process and equipment, in this case hydrocyclone operation.

Vibration monitoring and signal analysis have been used to study the feed distribution characteristics of parallel Dense Medium (DM) cyclones in a coal preparation plant. The method is based on the concept that the monitoring of vibrations on the external surface of the cyclone can yield the frequency and strength of particle impacts (particularly for larger particles near entry and exit points). Accelerometers for measuring vibrational accelerations were mounted near the feed inlet, underflow spigot and overflow cap. Relatively large vibrations were noted in the region of the overflow cap, reflecting the energy of particle/wall impacts in that region due to the flow regime within the cyclone. Results indicated that vibration measurements are a superposition of a large number of transients caused by individual particle impacts.

Summary of the Invention

According to the present invention a system is provided which is capable of monitoring acoustic emissions from a moving machine.

The invention includes within its scope systems for monitoring moving substances within a stationery or moving machine.

The system in broad terms is directed at monitoring mechanical wave emissions from inside the machine and the surface of the machine, as well as associated components of the machine which are affected by the machine's operation.

Summary of the Invention

According to a first aspect, the invention provides a system for monitoring mechanical waves from a machine which in operation has moving particulate matter therein, the system including at least one sensor located on the machine at a location away from the central axis of the machine, the sensor(s) being for sensing mechanical waves and including a transmitter for transmitting signals representing the sensed mechanical waves to a receiver at a location remote from the sensor(s), a data processor connected to the receiver for receiving signals from the receiver which signals represent the mechanical waves and processing the signals to produce output signals for display on a display means, wherein the output signals for display represent one or more parameters indicative of mechanical waves emitted from the machine over a predetermined period of time.

It is preferred that the output signals represent a number of acoustic events occurring within the machine, amplitudes of the acoustic events and data relating to the position of the acoustic events.

It is preferred that the system includes a plurality of sensors each for detecting acoustic emissions from inside the machine and from the surface of the machine.

It is preferred that the system includes a plurality of sensors spaced around the periphery of the machine to enable polar co-ordinates of the origin of emissions to be located.

It is preferred that the sensors are equispaced around the periphery of the machine.

According to one embodiment of the invention sensors are arranged in an array around the machine and along the length of the machine to enable a three-dimensional co-ordinate axis to be plotted of the location of the origin of emissions from the machine.

It is preferred that these sensors are removably attached to the outer surface of the machine.

According to one embodiment the transmitter associated with each sensor is located away from a detector part of the sensor.

According to one embodiment one or more transmitters of the sensors are removably attachable to the machine.

It is preferred that the system includes at least one proximity detector for monitoring the location of the sensors at a predetermined time.

According to one variation of the present invention the data processor includes a timing means for calculating the location of the sensor(s) at a predetermined time.

It is preferred that the timing means output data relating to the position of the sensor(s) at a particular time, based on data received either from the proximity detector(s) or/and data received relating to the movement of the machine.

It is preferred that the data processor receives signals from the receiver, which signals include data relating to the frequency of vibrational events occurring within the machine and the amplitude of the vibrational events at particular locations within the machine.

It is preferred that the sensor(s) includes an

accelerometer.

It is preferred that the sensor includes a power supply.

The power supply may be a solar cell.

According to another embodiment of the present invention the power supply is a 12 volt gel cell rechargeable battery.

Battery charging may be achieved using two solar panels mounted on opposite sides of the mill or alternatively other recharging methods include an inertial generator, offtake from the electric drive, or some other source that provides a continuous power supply.

According to another aspect of the present invention there is provided a method of analysing operational parameters of a machine having a moving particulate material therein, the method including the steps of recording data representing a number of mechanical events occurring within the machine over a predetermined period of time, the amplitude of the mechanical events occurring over the predetermined period of time and positional data relating to the position of the mechanical events occurring within the machine, displaying a graphical representation of the recorded data, the graphical representation including parameters relating to the number of mechanical events, the amplitude of mechanical events and the position of mechanical events occurring within the machine during the machines operation.

Preferably the mechanical events include mechanical events.

It is preferred that the graphical representation includes data on the radial and angular position of each vibrational event.

Preferably the graphical representation shows the number of vibrational events on a polar co-ordinate graph.

According to one embodiment the step of displaying includes displaying a histogram of variables relating to the number of vibrational events occurring over

the predetermined tim .

The present invention also includes within its scope graphical representation of the recorded data in a rectilinear co-ordinate system and three dimensional co-ordinate system.

According to one embodiment of the present invention the step of displaying includes displaying a graphical representation of the recorded data on a data processing monitor using 3D graphics which simulate the machine and provide a graphical representation of the moving particulate material within the machine.

It is preferred that the step of displaying includes highlighting regions within the machine which have vibrational events liable to cause maximum damage to a component of the machine.

According to another variation of the present invention the graphical representation includes a colour scheme for colouring regions of the graphical representation according to features of vibrational events occurring at positions of the vibrational events.

According to another aspect of the present invention there is provided a method of controlling operational parameters of a machine having a moveable substance therein, the method including the steps of recording data representing a number of mechanical events occurring within a machine over a predetermined period of time, amplitude and/or frequency of the mechanical events occurring over the predetermined period of time and position data relating to the position of the mechanical events over the predetermined period of time, determining zones within the machine which are subject to predetermined levels of wear and altering the machine operational characteristics to reduce the levels of wear for the zones.

Preferably the mechanical events includes vibrational events.

It is preferred that the step of determining zones, includes processing the recorded data with data

relating to the substance or substances within the machine, and dynamic properties of the substance(s) to produce a level of wear indication parameter for a plurality of zones within the machine.

It is preferred that the method includes operating a data processor which includes recorded model data relating to wear characteristics of the machine as a function of a plurality of parameters which may include one or more combinations of the following:

The number of vibrational events occurring within the machine, the amplitude of the vibrational events occurring within the machine, the position of the vibrational events occurring within the machine, the mass of the particulate material and other material substance(s) within the machine, the size of the particulate matter within the machine, the volume of particulate matter within the machine, the volume of space within the machine, the shape of the machine and other parameters which are likely to affect the wear characteristics of the machine.

Alternatively the method of controlling the machine includes determining the efficiency of operation of the operational characteristics of the machine.

It is preferred that the method includes the step of processing the recorded data with other data relating to characteristics of the particulate matter and machine to determine the efficiency of operating characteristics of the machine.

The operating characteristics could include the efficiency of a crushing operation over a predetermined period of time.

It is preferred that the method includes the step of increasing or decreasing the speed of operation of the machine, including rotation or reciprocating motion of the machine and/or alteration of rate of feed of particulate matter to the inside of the machine.

It is preferred that the method includes the step of maximising a predetermined operational parameter of the

machine. This may include maximising the amount of crushing of a material within a machine that is a crusher. Preferably the graphical representation includes any one or more of the following, Fourier analysis, histogram, signal moment, surface vibration event analysis and wavelet analysis. Other analysis techniques include Sepstrum and Homomorphic Deconvolution techniques of non-linear signal processing.

Preferably the method includes the step of truncating data recorded to an integral number of mill rotation periods.

The method preferably includes the step of recording data representing frequency of vibrational events occurring over a predetermined period of time.

The method may also include the step of measuring or monitoring volumetric load in the machine by identifying the toe and shoulder positions of particular matter within the machine.

Preferably the method includes obtaining a polar co-ordinate plot of the volumetric of particulate matter within the machine.

It is preferred that the recorded data is processed to provide a display of the location of high energy events throughout a polar plot of the machine.

It is preferred that the method includes recording data for different operational parameters of the machine including speed of revolution.

Preferably the method includes identifying a range of angles within which greater numbers/amplitude/frequency of vibrational or other mechanical events are occurring.

It is preferred that a value

$$f = \frac{(\theta - \sin\theta)}{2\pi}.$$

is able to be produced by the method to provide a first approximation for volumetric filling of the machine, where θ is the angle (radiance) between the toe and

shoulder positions of the particulate material.

It is preferred that the method includes producing a preferred operational speed for the machine in order to minimise the number/amplitude/frequency of vibrational events occurring within the machine for a particular value of θ.

Preferably the method of controlling operational parameters of a machine includes using a value of F for a particular amount of particulate matter within a machine in order to identify a preferred speed of operation of the machine whereby the number/amplitude/frequency of vibrational events occurring within the machine is minimised.

Minimisation of number/amplitude/frequency of vibrational events occurring within the machine can be produced by choosing an operational speed of the machine which minimises the value of f.

It is preferred that impact on the machine caused by the toe and shoulder of the particulate matter is able to be monitored in order to minimise wear and tear on the liner or other parts of the machine.

Brief Description of the Drawings

Preferred embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows a schematic of grinding media behaviour in a SAG Mill rotating at abnormally high speed;

Figure 2 shows a schematic of a basic system for monitoring acoustic emissions from a rotating machine;

Figure 3a shows a graphical representation of an accelerometer response on a rotating SAG Mill as a function of time;

Figure 3b shows a plot of standard deviation of sampled signal as a function of mill revolution number. Manipulated variables are feed rate and mill rotation speed;

Figure 3c shows standard deviation of the sample

signal as a function of mill revolution number. Manipulated variables are pulp density and ball addition;

Figure 4a shows a low rotation rate polar contour plot of the natural logarithm of a number of vibrational events (E^{05} number intervals) as a function of energy (volts^2) in the radial direction and mill rotation phase angle (degrees anti-clockwise from the 3 o'clock position) in the azimuthal direction. Contours of large numbers of events are at low amplitudes. The mill is rotating clockwise;

Figure 4b shows a high rotation rate polar plot of the natural logarithm of the number of vibrational events ($E^{0.5}$ number intervals) as a function of energy (volts^2) in the radial direction and mill rotation phase angle (degrees anti-clockwise from the 3 o'clock position) in the azimuthal direction. Contours of large numbers of events are at low amplitudes. The mill is rotating clockwise;

Figure 4c shows a diagram of amplitude weighted average event phase angle as a function of revolution number and operating conditions;

Figure 5 shows a graphical representation of power spectral density plot upto 1,000 Hz, the parameters are 2^{16} FFT length, 2^{15} number of samples overlap, FFT length Hanning windowing and nil detrending;

Figure 6 shows a graphical representation of power spectral density plot upto Nyquist frequency, the parameters are 2^{10}FFT length, 2^9 number of samples overlap, FFT length Hanning windowing and nil detrending;

Figure 7a shows a histogram of the natural logarithm of the total number of vibrational events occurring within an SAG Mill, as a function of event amplitude;

Figure 7b shows a decimated signal for 18 revolutions of data. Decimation of raw signal by a factor of 10^3 by successive application of factor of 10 re-sampling and filtering;

Figure 7c shows a PSD plot upto 1Hz from decimated signal (2^{11} FFT length and Hanning windowing,2^{10} number of samples overlap, and nil detrending.);

Figure 7d shows a spectrogram plot upto 25,000 Hz (2^{12} FFT length and Hanning windowing, 2^{11} number of samples overlap and nil detrending);

Figure 7e shows a spectrogram plot upto 1,000 Hz (2^{12} FFT length and Hanning windowing, 2^{11} number of samples overlap, and nil detrending);

Figure 8 shows a graphical representation of a SAG Mill gross power as a function of the standard deviation of surfaces for three different mill speed settings; and

Figure 9 shows a graphical representation of pulp density (percent solids) as a function of the standard deviation of surface vibrations for two different sets of mill conditions.

Preferred Embodiment of the Invention

An example of a system for monitoring vibrational events occurring within an SAG 10 Mill will now be described.

An SAG Mill 10 consists of a metal cylindrical drum containing metallic ball bearings and particulate matter to be crushed.

The surface of the mill 10 is provided with an accelerometer 11 which is movably fixed thereto and includes a radio transmitter.

A solar panel 12 is electrically connected to the accelerometer 11 to provide a power supply.

A radio receiver 13 is connected to a stationery part of the SAG Mill framework and receives data transmitted by the radio transmitter of the accelerometer 11.

The radio receiver is hardwired to a terminal block 14 and a laptop computer 15 is able to be connected to the terminal block to receive data sensed by the accelerometer.

One or more proximity switches are located on the rotating part of the mill 10 to enable the position of the accelerometer to be located relative to the rate of rotation of the mill.

The operation of a SAG mill 10 results in the generation of high frequency surface waves on the outside of the rotating shell due to collision events within the mill. Monitoring of surface waves with a sensitive accelerometer therefore provides information on events inside the mill, particularly impacts of grinding media on the liner The grinding media is defined here as non-ore (often steel balls) and ore particles (the larger size fractions of which contribute to impact grinding). However, measurements of surface vibrations on the outside of the shell do not simply reflect local impact events on the inside of the liner. All of the components of the mill behave to some extent as elastic media, permitting the propagation of waves generated by collision events within the mill, 'flexing' of the mill shell during rotation and external sources such as the drive motor and girth gear. Transverse surface vibrational waves propagate around the inside of the liner and-around the outside of the shell. Meanwhile longitudinal sound waves travel through the charge and between the liner and shell. An accelerometer mounted on. the outside of the shell registers normal acceleration due to waves transversely propagating around the shell. These waves are damped in accordance with the properties of the elastic media between the point of wave registration and the origin of the causative event. Hence vibrational events as measured by an accelerometer can be expected to be due to causative events over a limited range of locations within the mill and associated assembly. However, for preliminary analysis it is assumed that the vibrations are locally, generated by collision events inside the mill, adjacent to the accelerometer.

The behaviour of grinding media in a rotating SAG mill 10 is usually characterised in a similar manner to

balls in a ball mill. Grinding regions are expected to consist of the following (see Fig. I):

- shearing layers of media near the base of the charge article shatter and cleavage (region 1).
- tumbling media from high to low gravitational potential near the top of the charge causing particle shatter (region 2).
- cataracting media impacting in the 'toe' region of the. charge causing particle shatter (region 3).
- some abrasion breakage between the grinding media and the liner in the contact region between the charge and the liner between the "toe and shoulder" (nil net force) of the charge (region 4).

Higher mill rotational speeds cause cataracting grinding media to directly impact on the liner above the 'toe' of the charge (Fig. 1, section 5). Liner 'Wear is approximately proportional to the square of the mill speed and increases with grinding media size due to the consequent increase in impact energy. It is known that the presence of mineral slurry is very effective in damping the impact force of grinding media on the liner. Hence liner cracking is interpreted as evidence of a problem of excessive direct impact of grinding media on the liner. The lifter profile also plays a strong role in determining the trajectory of cataracting grinding media and hence both the location and energy of impact of the grinding media on the charge or the liner wall. A rectangular lifter profile is thought to result in the widest profile of cataracting events for a given mill speed and charge volume This could be interpreted as meaning that a rectangular lifter profile leads to the highest inherent likelihood of large impact events directly on the liner. The composition of the liner itself directly influences both impact and abrasion resistance. Use of a liner material that is strongly resistant to abrasion often results in low impact resistance and hence an increased propensity to cracking. Other causes of liner wear are

corrosion (in wet mills) and abrasion. However, these sorts of wear are not expected to be manifested as liner cracking. A non-intrusive means of quantifying the spatial position and intensity of the various types of grinding behaviour in SAG mills would be very useful for process monitoring and control. SAG mill operators are very keen to use a technique that provides a reliable measure of mill load Monitoring of the frequency and spatial position of large energy particle impacts would also be very useful for monitoring and controlling SAG mill liner wear.

Apparatus

The surface vibration monitoring system can be configured in two ways - basic or advanced. The following provides a description of each configuration.

Basic system

The surface vibration monitoring apparatus consists of a Bruel and Kjaer accelerometer type 4393 connected to a Bruel and Kjaer charge amplifier type 2634. The output from the charge amplifier is connected to a microphone beltpack transmitter (AKG type BT5 1) powered by a 12 volt gel-cell rechargeable battery. Battery recharging is achieved using two solar panels mounted on opposite sides of the mill. Transmitted data is received using a microphone wireless receiver (AKG type SR5 1) with two modified extended antennae.

Receiver output is connected to a terminal block and ribbon cable. The ribbon cable is connected to fast data acquisition PCMCIA DAQCard-A1-1 16E -4 linked to a laptop computer.

A magnetic proximity pad was mounted on the mill ;at 3 o'clock looking from the discharge end. The detector/switch was mounted off the mill and connected to the terminal block mentioned above. The switching signal from the proximity detector is used as a trigger for logging of the accelerometer signal.

The software (written in LabView) can be triggered manually or digitally. Triggering occurs when the

magnetic pad and detector/switch comes in close proximity as the mill rotates and a 5 volt signal changes to 0 volts. Data acquisition then begins with the data being read into a rolling buffer and stored into five data arrays. Acquisition rate is adjustable up to 100k samples/s. At the end of the acquisition process, the mean of the arrays is calculated as well as the standard deviation. This; data is stored in a file retrieved using Excel and contains the following information:

- Time in seconds from when the system first began logging.
- Signal mean in volts.
- Signal standard deviation in volts
- Sample size.

Unprocessed raw data was also saved in binary format for further data processing analysis as mentioned later.

Advanced system

The advanced system includes the basic system described above plus one or more additional accelerometers and associated equipment. The accelerometers are of the same type as described above. The main difference with the advanced system is an improved radio transmission and reception apparatus to enable data acquisition down to lower frequency ranges (around 1 Hz). The apparatus consists of an Adam module digital radio modem and reception system linked to an on-mill computer that performs preliminary signal processing before transmission to the logging computer. The improved system can run in parallel beside the basic system and data is logged and saved on the same laptop. The advanced system requires extra power for operation so extra solar panels are required compared with the basic system. The advanced system can consist of multiaccelerometers either in basic or advanced configuration to investigate low frequency events, ev nt spatial localisation, and events occurring on the ends of the mill. Signal data processing techniques are

then used to determine surface vibration features for given operating conditions. A schematic of the basic system attached to the shell of a SAG mill is shown in Figure 2.

EXPERIMENTAL DESIGN

Two series of surface vibrations monitoring runs were conducted on the SAG mill at the Red Dome gold mine, using the basic system of apparatus. The first was a limited series of test runs at different mill operating conditions essentially to test the system and establish that under severe plant duty the system produced data that could be processed. Qualitative evaluation of the data clearly indicate that features of the data (in the form of a voltage-time trace) changed at different operating conditions. Features identified were: the minimum signal strength, length of time between start of signal and proximity signal, length of time for events to return to background, maximum signal size, number and position of high frequency/high energy spikes, amplitude of high energy spikes and variation between successive revolutions. These results highlighted the necessity for further surface vibrations monitoring of the Red Dome SAG mill using a conditional experimental design so that the influence of only one variable could be measured in the context of changes in surface vibration features. Thus, this approach would better characterise the potential relationships between features and operating settings.

The second series of test runs at Red Dome conformed to the conditional experimental design approach. A total of 23 test runs were conducted to investigate how surface vibration features changed with one manipulated operating variable at a time. The manipulated operating variables were tonnage rate, mill speed, mill discharge density and ball addition. In addition to acquiring surface vibration information, both control system data and physical plant measurements were taken at each set of conditions to confirm test run validity.

Faster acquisition speeds were possible for the

second series of tests and a range of data was collected at each manipulated mill condition. A 'normal' run was conducted first at a scan rate of 5 x 10^4 scans/s with raw data and statistical averages of the mean and standard deviation being saved. Then a 'fast' run, with acquisition rate increased to 1 x 10^5 scans/s, was conducted for a duration of 1 X 10^6 scans. Following the fast run, a run using the original LabView VI written for the first series of lest runs was conducted at the same speed as a 'normal' run listed above and saved to a binary file. Lastly, a 'long' run was conducted with the acquisition speed set at 5 x 10^4 scans/s for a duration of 1 X 10^6 scans. Listed below are the range of conditions for the manipulated operating variables:

Manipulated variable - tonnage (range 170-200 tph)

- Mill speed - 11.8 rpm
- No ball addition
- Pulp density - 72% solids w/w.

Manipulated variable - speed (range 12.3-13.8 rpm)

- Tonnage - 2 10 tph
- No ball addition
- Pulp density - 72% solids w/w.

Manipulated variable - ball addition (no-yes 1 kibble)

- Tonnage - 2 10 tph
- Mill speed - 13.8 rpm
- Pulp density - 72% solids w/w.

Manipulated variable - pulp density (65-72% solids w/w)

- Tonnage - 210 tph
- Mill speed - 12.5 rpm
- No ball addition

Manipulated variable - pulp density (72-82% solids w/w)

- Tonnage - 210 tph
- Mill speed - 14.5 rpm
- No ball addition

A number of other tests were conducted at intermediate conditions for tonnage and speed within the range listed above.

DATA ANALYSIS TECHNIQUES

The goal of the data analysis techniques is to derive quantitative measures and qualitative visualisations based on the response of the accelerometer to shell vibrations that can be correlated with SAG mill operating conditions. This enables vibration measurements to be used for process condition monitoring and as an input to unit control. The measures are also useful for inference of the rate of liner wear as a function of operating conditions in with the SAG mill.

Surface vibrational waves as registered by an accelerometer are characterised by a wide variety of measures. The first step in data processing prior to deriving any of these measures is to truncate the data to an integral number of mill rotation periods. This is done in order to ensure that there is no bias in the data due to the sensor detecting changes in mill conditions as a function of rotational position of the outer shell.

The concept of a shell surface vibration event is important in the data processing. Such an event is defined as a positive deviation from nil accelerometer response. The amplitude is taken as the peak accelerometer response associated with a positive acceleration. This is in accordance with a propagating surface wave inducing a positive acceleration in an accelerometer corresponding to a normal stress outwards from the shell. It is hypothesised that collision events within the mill, particularly grinding media/liner events, will induce a strain that will propagate as a wave to the outside of the shell and be initially sensed as a positive acceleration. A wave train due to a collisional event should be composed of an initial relatively large, positive acceleration followed by negative and positive oscillations of rapidly decreasing amplitude. It is expected that the accelerometer will detect only the first few oscillations of any wave train associated with a particular collisional event. Negative accelerations are interpreted as part of a wave train

belonging to a previous positive acceleration and are hence discarded in terms of registering distinct events. Subsequent positive oscillations in a wave train are expected to be highly damped due to the low elasticity and high damping properties of the liner and the outer shell. Hence it is reasonable that each sequence of positive acceleration defines a vibrational event caused by a particular media/media or media/liner collision within the mill.

The various measures used to characterise surface vibrational waves are as follows:

1 Mean and standard deviation of the sampled signal.

2. Power spectral density of the sampled signal.

3. Histograms of sampled signal amplitude. This includes histograms of sampled signal, absolute value of sampled signal and the natural logarithm of the absolute value of the sampled signal.

4. Total number of signal samples and the ratio of large to small amplitude samples. The cut-off amplitude between large- and small-scale accelerometer responses is user defined.

5. Mean and standard deviation of the amplitude of surface vibrational events.

6. Mean and standard deviation of the phase (in terms of the position of the accelerometer in the rotation cycle of the mill) of surface vibrational events.

7. Mean and standard deviation of the phase (in terms of the position of the accelerometer in the rotation cycle of the mill) weighted by amplitude of surface vibrational events.

8. Histograms of surface vibrational event magnitude. This includes histograms of amplitude and the natural logarithm of the amplitude of events

9. Total number of events and the ratio of large to small amplitude events. The cut-off amplitude

between large- and small-scale accelerometer responses is again user defined.

10. The energy of the sampled signal as derived from the power spectral density, in the frequency bands 0-100 Hz, 100-300 Hz and 500-700 Hz and around 18 kHz. These frequency bands are deemed by experience to contain most of the surface vibrational wave energy information that varies with mill operating conditions.

11. The total energy of the sampled signal derived from both the power spectral density and the amplitude versus time accelerometer response.

12. Contour plot of vibrational event numbers as a function of SAG mill phase angle and event amplitude. Event amplitude and phase angle are identified as associated with the maximum positive excursion of the accelerometer response for any particular event. The natural logarithm of surface vibrational event numbers is plotted in order to emphasise the position angle of relatively large amplitude but infrequent events.

13. Spectrogram time-dependent frequency analysis of the sampled signal.

14. Decimated (decreased sampling rate) versions of the signal and associated power spectral density analysis.

All the above measures are derived for each revolution of a continuous monitoring period and over the entire integral number of mill revolutions of the same. The signal analysis software has been implemented in the MATLAB technical computing language. However, any and all of the components of the software could be implemented in -a variety of other programming languages.

A typical accelerometer response trace as a function of lime for a rotating SAG mill is shown below (Fig. 3). In this case four full mill revolutions of data (5×10^4 samples per second), previously defined as a long run, are recorded. There is clear evidence of periodicity in the amplitude of events registered by a single

accelerometer as a function of mill rotation angle.

The standard deviation of the surface vibration sampled signal is an important measure of the condition of the material within the moving machine. Figures 3b and 3c show the standard deviation of the sampled signal from a SAG mill over a single revolution as a function of mill revolution number for a range of manipulated operating variables. Figure 3b shows that on average, the signal standard deviation is substantially higher at the low rather than the high feed rate and at the high rather than the low mill speed. The former result is thought to indicate a low filling level under low feed rate conditions at dynamic steady state and hence relatively poor cushioning of high energy grinding media impact events on the liner. The latter is thought to be due to the increase in both energy and frequency of grinding media impacting directly on the liner.

Figure 3c shows that the addition of balls actually decreases the variability of the standard deviation across mill rotation periods, but increases its mean value. Figure 3c also shows that at high speed, a high pulp density condition leads to a decreased standard deviation. This may be due to increased dampening of grinding media collisions with pulp density. At low speeds the standard deviation actually increases with pulp density. Both Figures 3b and 3c demonstrate considerable quasi-periodic variability of the signal standard deviation between rotation periods. This may be due to non-steady motion of the total charge at frequencies less than or equal to the rotation of the mill, even when dynamic steady state power draft conditions apply.

A polar contour plot of vibrational event numbers as a function of SAG mill rotation phase angle and event magnitude allows vibration events to be identified with particular locations in the rotation cycle. Differences may be identified in SAG mill operation both between rotation periods and with changes in mill operating conditions. The

position of either the event amplitude or energy weighted average phase angle of acoustic events is a simple and valuable quantitative measure in this regard.

Figure 4a shows a surface vibration (loosely termed acoustic emission or AE) event numbers polar contour plot for an "average" SAG mill revolution, based on 19 single revolutions of data obtained under low speed experimental conditions. There is clear evidence of the expected localisation of large events in regions where the charge is thought to be in contact with the liner. In particular, there are greater numbers of relatively high-energy events in the ~290-330 degrees region where it is expected that cataracting media impact on the charge. These events are thought to identify the position of the "toe" of the charge. Hence it is inferred that there is strong damping of AE waves as they propagate around the shell. However, Figure 4a also shows that there is a registration of lower strength AE events in regions where the charge and grinding media are not expected to be in contact with the shell liner. These lower energy signals are most likely due to surface AE waves propagating around the shell from other regions. The prominence of these signals at positions above that expected for the "toe" of the charge is in accordance with the view that as the sensor rotates through these positions it is actually registering events that have originated further down the shell. Nevertheless, it seems likely that very high-energy events recorded by the accelerometer at a particular phase angle do reflect collisions in the adjacent region of the inner liner. The identification of the boundaries of contact of the SAG mill charge with the liner is potentially important as this information may be used to deduce the charge volume and hence indicate changes in internal conditions as changes in operating conditions occur.

Figure 4b is an AE event numbers polar contour plot for high rotation rate conditions (14.5 rpm, 72% pulp density and 210 t/h). The high-energy events have now

clearly split into two peaks at ~290 degrees and ~330 degrees (this is even clearer for plots based on individual rotation periods). These peaks are postulated to represent respectively the 'toe' of the charge and a region where cataracting grinding media directly impinge on the liner. The monitoring technique can therefore discriminate large energy impacts above the "toe" of the charge. This detection of grinding media direct impacts on the liner can be used as a predictor of liner wear rate.

Figure 4c shows the amplitude weighted average AE event phase angle over a revolution as a function of revolution number. As expected from examining Figures 4a and 4b, the average event phase angle is in the quadrant associated with the "toe" of the charge. There are clear differences between the average phase angle for the different operating conditions previously mentioned. The average position angle associated with low feed rate conditions is substantially less than the same measure for high feed rates. This is physically reasonable, as one would expect the steady state volumetric loading to be less under low feed rate conditions. The average phase angle for a high rotation rate is clearly larger than the corresponding measure for a low rotation rate. Again, this is physically reasonable as one would expect a high rotation rate to result in more grinding media impacting higher up the liner wall. Increasing the pulp density or adding grinding balls while maintaining other operating conditions lowers the average position angle. These are plausible results if increases in pulp density and ball addition are considered to stabilise the bulk behaviour of the charge. The significant changes in average event phase angle that occur with mill rotation number may indicate bulk movement of the charge.

Figure 5 shows a typical power spectral density plot obtained for surface vibration waves detected by an accelerometer, based on the same set of data. Spectral features are readily apparent near the DC channel (< 100

Hz), around 100-200 Hz and near 600 Hz. Finer spikes in the power spectrum can be seen at frequencies below about 400 Hz. Figure 4d shows PSD plots for extremes in mill speed and feed rate. Spectral features that are sensitive to mill operating conditions are apparent for frequencies < 100 Hz, around 100-200 Hz and near 600 Hz. Surface vibration power is higher at low feed rates at frequencies > ~100 Hz. High mill speeds result in increased surface vibration power at low frequencies (<~100 Hz). The total power associated with the signal PSD is substantially higher for both the low feed rate (~40%) and high speed (~30%) operating conditions in comparison with values for the respective high feed rate and low speed operating conditions. Sharper spikes in the power spectrum can be seen at frequencies below ~500 Hz in the case of high mill rotation speed. All these features are well above the background noise level and are probably related to bulk motion of the charge. In Figure 5, the frequency range was restricted to a maximum of 1000 Hz, because ~80% of the AE signal power was within this range. Power spectral density plots have also been obtained up to the Nyqvist frequency (half the sampling rate).

Fig. 6 shows an example based on the same data. A prominent spectral feature is apparent at a relatively high frequency (around 18000 Hz) and experience has shown that this feature is sensitive to mill operating conditions. Fourier analysis is used in order to try to represent the accelerometer response to surface vibrational waves in terms of a superposition of sinusoidal waves at characteristic frequencies. As vibrational events are discrete entities, another fruitful approach might be wavelet analysis.

Figure 7a shows a histogram of the number of vibrational events as a function of the amplitude of the accelerometer r sponse associated with the event. This is an important way of demonstrating both the total number and distribution with amplitude of vibrational events as a

function of mill operating conditions. In this manner operating conditions that lead to a relatively large number of very high amplitude vibrational events can be easily identified. Such cases correspond to conditions of high liner wear. Conversely, concentration of events at a relatively low amplitude indicate ineffective particle grinding within the SAG mill.

Power spectral density analysis associated with multiple revolutions of surface vibration data can be used to obtain information on periodicities in charge behaviour at very low frequencies - even down to and below the frequency of rotation of the mill. The process used for this type of analysis is successive decimation of the raw sampled signal in order to decrease the sampling rate of the data. The decimation process filters the input data with a lowpass filter and then resamples the resulting smoothed signal at a lower rate. Figures 7b and 7c show the decimated signal and power spectral density plot obtained via decimation of eighteen revolutions of the surface vibration signal prior to the addition of grinding media. Successive decimation of the signal by factors of ten was used to reveal energy peaks at the rotation frequency of the mill (0.23 Hz) and several higher harmonics. Spectral features sensitive to mill operating conditions are present over the entire range of frequencies up to those shown in Figs. 5 and 6.

Time-dependent frequency analysis can be used to gain further knowledge of the internal behaviour of the mill. A spectrogram computes the windowed discrete-time Fourier transform of a signal using sliding windowing. Figures 7d and 7e are spectrograms of a single rotation period (~5 seconds) of data associated with the low feed rate mill operating condition. The colour intensity plot displays the power of the signal at each sampling frequency and time.

Figure 7d shows strong spectral features below ~5 kHz and a distinct feature at ~18kHz. This is in accordance

with power spectral density analysis as demonstrated in Figure 6. However, such plots also show that the frequency distribution of the power of the signal is not the same at all times over a rotation period. This is more clearly demonstrated in Figure 7e, which shows that power in the range ~200-1000 Hz is largely restricted to a distinct time range in the mill rotation period. The spectral feature at ~600 Hz previously identified by power spectral density analysis can therefore be used as a measure of the boundaries of the charge during the mill rotation period, corresponding to both the 'shoulder' and 'toe' position of the charge. Analysis of spectrogram (and power spectral density) plots over many rotation periods and for different mill operating conditions reveals the sensitivity of these measures to operating conditions. Spectrogram plots can also be represented in a polar fashion (similar to Figures 4a and 4b) in order to directly determine the shoulder and toe positions in terms of phase angles.

The boundaries of the SAG mill charge as determination of the weighted average surface vibration event phase angle can then be used to provide a first approximation for the volumetric filling of the mill. Simple geometrical considerations lead to the following

$$f = \frac{(\theta - \sin\theta)}{2\pi}.$$

expression for the fractional filling f of the mill.

Here θ is the angle (radians) between the toe and shoulder positions of the charge.

CORRELATIONS BETWEEN SURFACE VIBRATION MEASURES AND MILL OPERATING CONDITIONS

As mentioned in the previous section, mean and standard deviation of sampled signal was calculated for all test runs. It was postulated that the standard deviation would be a useful measure of activity in the mill at a given set of conditions. The traces show that the amplitude of the signals and the number of high amplitude (energy) signals changes for different conditions. These changes are

then likely to change the standard deviation thereby creating an opportunity to establish relationships between the surface vibration features encompassed in the standard deviation and actual mill operating variables.

Fig 8 shows a plot of standard deviation and mill gross power for three different mill speed settings.

Under normal operating conditions the mill gross power corresponds to the overall load level in the mill i.e the higher the gross power, the higher the load level. Other manipulated variables, namely ball addition and pulp density, were held constant. At each speed, the relationship between standard deviation and gross power is linear with a negative slope. An increase in the mill gross power (load level) leads to a decrease in the standard deviation of the signal. This result is consistent with experience where the mechanism at play is thought to be increased damping as a result of the higher load level in the mill. The fitted equation for each speed differs and is likely to be indicative of some other effects that are at work. Similar relationships are being developed for other surface vibration measures listed in the previous section. The relationships shown in Fig. 8 mean that for a given speed, the standard deviation measured relates directly to the gross power of the mill which itself is an indirect measure of the load level.

Figure 9 shows a plot of the standard deviation against pulp density at two different mill conditions.

As expected, the relationships for the two conditions differ but are consistent with experience. Usually, at higher densities, the thicker slurry inside the mill acts as a more effective damper thereby reducing the severity of impacts on the shell. This assertion is reflected in the measured readings, which show lower standard deviation at higher density. Similarly at lower densities, higher surface vibration standard deviation was measured.

ALTERNATIVE SIGNAL ANALYSIS AND CORRELATION DETERMINATION

TECHNIQUES

The list of signal analysis techniques used above to characterise the surface vibration signals (including techniques based on Fourier analysis, histogram, signal moment and surface vibration event analysis) is by no means exhaustive. Wavelet analysis could also be productive given that the surface vibration signals are believed to be largely due to discrete (time bounded) collision events within the mill. The cestrum analysis and homomorphic deconvolution techniques of non-linear signal processing could also be utilised to further analyse the signals. Analysis of signals from multiple sensing devices at different locations on a single moving machine could entail the use of cross correlation / cross spectral density analysis in order to identify the position of origin (and initial intensity) of a vibration.

Correlations between features of the signal and the mill operating conditions can allow the use of surface vibration signals as 'soft-sensors' for machine/process performance and estimation of unknown plant variables. Correlations determined by regression-based analysis of surface vibration signals could be extended to include consideration of relationships between operating conditions and spectral features determined by various types of Fourier and/or wavelet analysis, additional moments and statistical measures of the sampled signal and features determined by event and histogram statistical analysis. Multiple regression and principal component analysis could be used to further investigate these linkages. Other intelligent analysis methods such as neural networks, genetic algorithms, self-organising method, fuzzy logic, cluster analysis, Kalman Filter, expert system and ARMAX/NARMAX regression-based models could be used to analyse the data and seek correlations relating to both operating conditions, other process features such as the charge particle size distribution and ultimately be used for process optimisation and control.

Linkages could also be sought to discrete element models and/or other models including phenomenal logical knowledge.

ALTERNATIVE TECHNOLOGIES AND APPLICATIONS

Applications of the surface vibration technique extend well beyond SAG mills to other grinding mills e.g ball mills, stirred ball mills, jet mills etc. The technique is also applicable to other comminution equipment such as crushers, impactors, and hammer mills. In fact any machine that processes material and a requirement exists for a better understanding of the mechanisms occurring inside both from a processing and condition monitoring viewpoint are potential applications of this technique. Machines, the operation of which would benefit with the application of [his technique, include but are not limited to:

- AG/SAG/ball/rod/vibratory mills
- Gyratory/cone/jaw/rolls crushers
- Vertical shaft impactors
- Hammer mills
- Vertical spindle mills
- Hydrocyclones/dense media cyclones
- Spirals
- Vibrating/DSM/banana screens
- Vibrating plate separation devices
- Flotation cells
- High pressure grinding rolls/ roller presses
- Any equipment requiring process or condition monitoring
- Rotary kilns and dryers and balling drums

Alternative technologies that may compete with this surface vibration technique are thought to be acoustic emission sensors, Le microphones, mounted on the mill and configured similarly to this technique. This set-up would allow acoustic emission features to be correlated against events occurring in the mill during each revolution. The hardware required to build this type of system, aside from

the sensors, is likely to be very similar to the surface vibration system described above. Another possibility is to enclose a mill with a mounting frame so that the microphones are positioned around the entire circumference of the mill but are mounted off the mill. It is somewhat doubtful whether this configuration is practicable.

The arrangements of experimental apparatus and signal analysis techniques as applied to .monitoring a SAG mill as described in this document have been advanced merely by way of explanation. Many modifications may be made thereto both for further monitoring of SAG mills and other material processing machines without departing from the spirit and scope of the invention which includes every novel feature and combination of novel features herein disclosed.

CLAIMS:

1. A system for monitoring mechanical waves from a machine which in operation has moving particulate matter therein, the system including at least one sensor located on the machine at a location away from the central axis of the machine, the sensors being for sensing acoustic waves and including a transmitter for transmitting signals representing the sensed mechanical waves to a receiver at a location remote from the sensor(s), a data processor connected to the receiver for receiving signals from the receiver which signals represent the mechanical waves and processing the signals to produce output signals for display on a display means, wherein the output signals for display represent one or more parameters indicative of mechanical waves emitted from the machine over a predetermined period of time.

2. The system as claimed in claim 1 wherein the receiver is located on a stationery surface separate from the machine.

3. The system as claimed in claim 2 including a power supply located on the machine.

4. The system as claimed in claim 3 wherein the or each sensor is located on an exterior surface of the machine.

5. The system as claimed in claim 4 wherein the data processor is adapted to produce output signals which represent a plurality of acoustic events occurring within the machine, amplitudes of the acoustic events and data relating to the position of the acoustic events.

6. The system as claimed in claim 4 or claim 5, including a plurality of sensors spaced around the periphery of the machine to enable polar co-ordinates of the origin of emissions to be located.

7. The system as claimed in claim 6 wherein the sensors are equispaced around the periphery of the machine.

8. The system as claimed in claim 3 or 4 wherein sensors are arranged in an array around the machine

and along the length of the machine to enable to a three dimensional co-ordinate axis to be plotted of the location of the origin of omissions from the machine.

9. The system as claimed in claim 6 or claim 7 including at least one proximity detector for monitoring the location of the sensors at a predetermined time, whereby data from the proximity switch is adapted to be communicated to the data processor.

10. The system as claimed in claim 7 wherein the data processor includes a timing means for calculating the location of the or each sensor at a predetermined time.

11. The system as claimed in claim 9 wherein the or each sensor includes an accelerometer which is adapted to transmit data relating to the frequency of vibrational events occurring within the machine and the amplitude of the vibrational events at particular locations within the machine to the transmitter.

12. A method of analysing operational parameters of a machine having a moving particulate material therein, the method including the steps of recording data representing a number of mechanical events occurring within the machine over a predetermined period of time, the amplitude of the mechanical events occurring over the predetermined period of time and positional data relating to the position of the mechanical events occurring within the machine, displaying a graphical representation of the recorded data, the graphical representation including parameters relating to the number of mechanical events, the amplitude of mechanical events and the position of mechanical events occurring within the machine during the machines operation.

13. The method as claimed in claim 2 wherein the graphical representation of recorded data includes mean and standard deviation of vibrational events occurring within the machine, power spectral density of vibrational events occurring within the machine and histograms of amplitude of vibrational events occurring within the machine.

14. The method as claimed in claim 13 including the step of measuring volumetric load of the particulate matter within the machine by identifying the toe and shoulder portions of the particulate matter.

15. The method as claimed in claim 14 wherein volumetric load is determined from a polar co-ordinate plot of events occurring within the machine.

16. The method as claimed in claim 15 wherein volumetric load is calculated for a range of angles in which events within the machine have greatest deleterious effect on the interior of the machine.

17. The method as claimed in claim 16 wherein a value for volumetric filling of the mill is produced from the recorded data and the value of volumetric filling

$$f = \frac{(\theta - \sin\theta)}{2\pi}.$$

where θ is the angle (radiance) between the toe and shoulder positions of the particulate matter.

18. A method of controlling operational parameters of a machine having a moveable substance therein, the method including the steps of recording data representing a number of vibrational events occurring within a machine over a predetermined period of time, amplitude of the vibrational events occurring over the predetermined period of time and position data relating to the position of the vibrational events over the predetermined period of time, determining zones within the machine which are subject to predetermined levels of wear and altering the machine operational characteristics to reduce the levels of wear for the zones.

19. A method of identifying the volumetric load of particulate matter within a machine including the steps of receiving data, representing a number of mechanical events occurring within the machine over a predetermined period of time, the amplitude of the mechanical events occurring over the predetermined period of time and positional data relating to the position of the mechanical

events occurring within the machine, processing the received data to identify toe and shoulder positions of the particulate matter within the machine whereby the location of maximum deterioration of an inside surface of the machine can be minimised.

20. The method as claimed in claim 19 wherein data is received for a plurality of speeds of the machine.

21. The method as claimed in claim 20 including the step of identifying the fractional filling *f* of the machine where

$$f = \frac{(\theta - \sin\theta)}{2\pi}.$$

with θ being the angle (radiance) between the toe and shoulder positions of the charge.

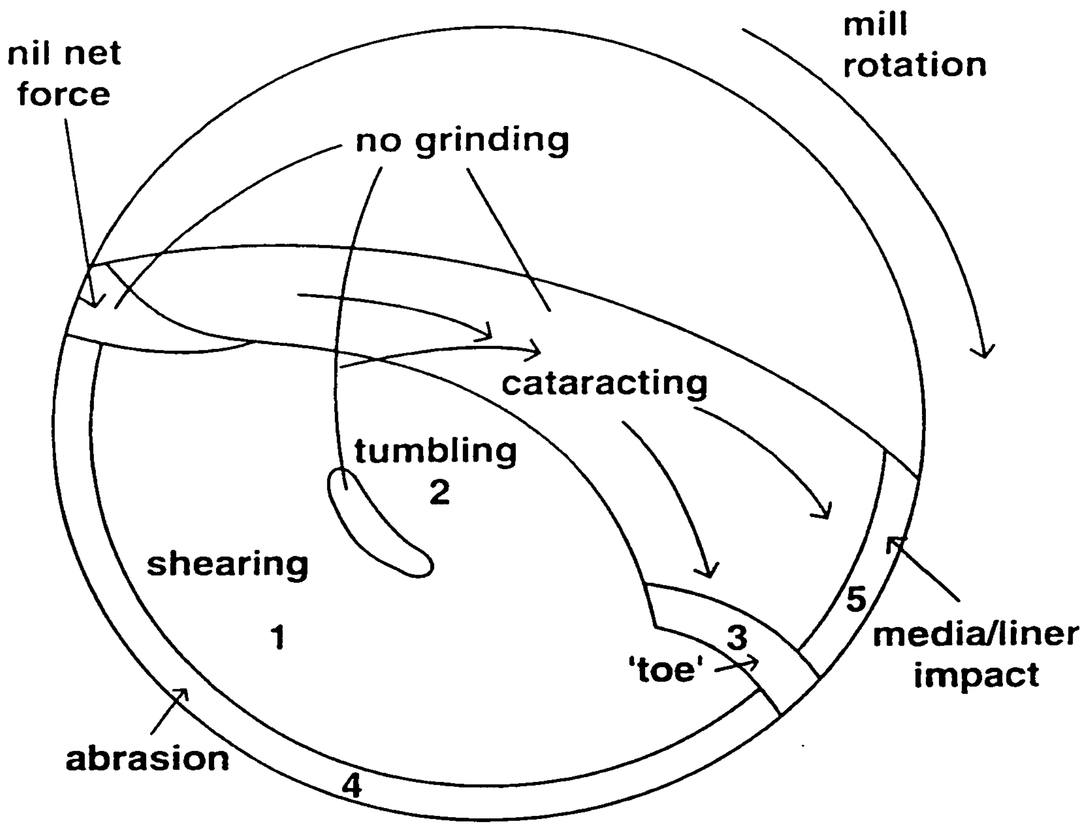

mill
rotation
nil net
force
no grinding
cataracting
tumbling
2
shearing
1
3
'toe'
5
media/liner
impact
abrasion
4

FIGURE 1

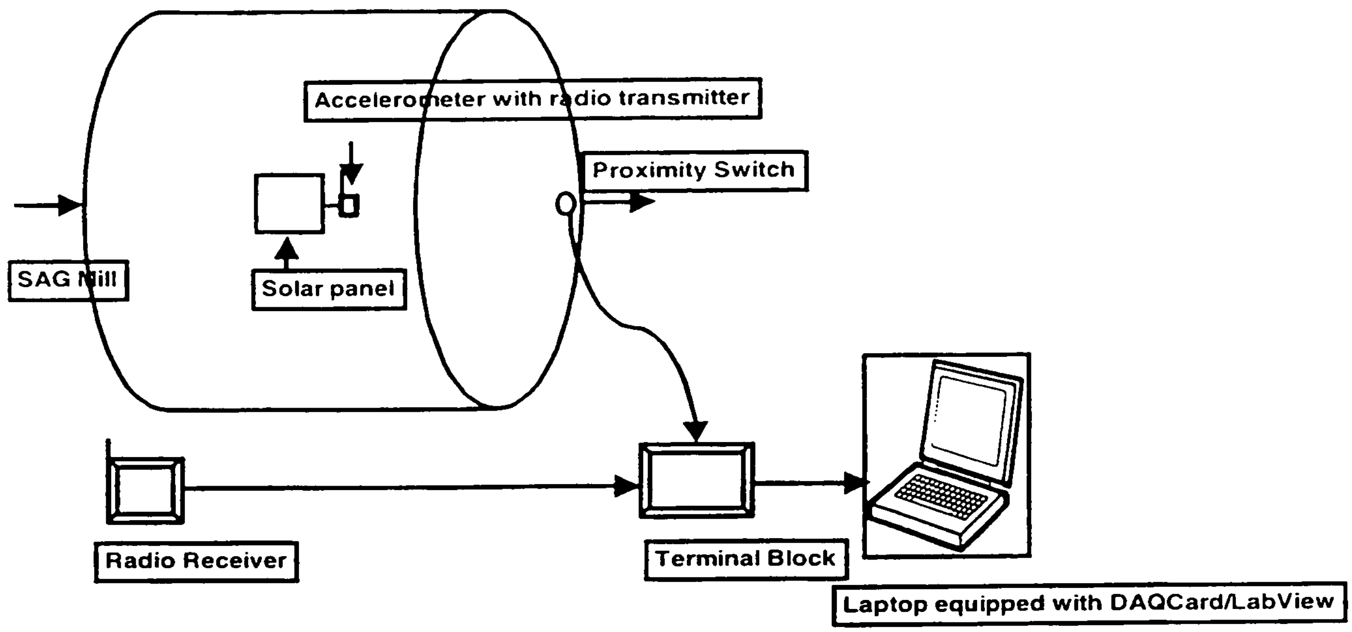
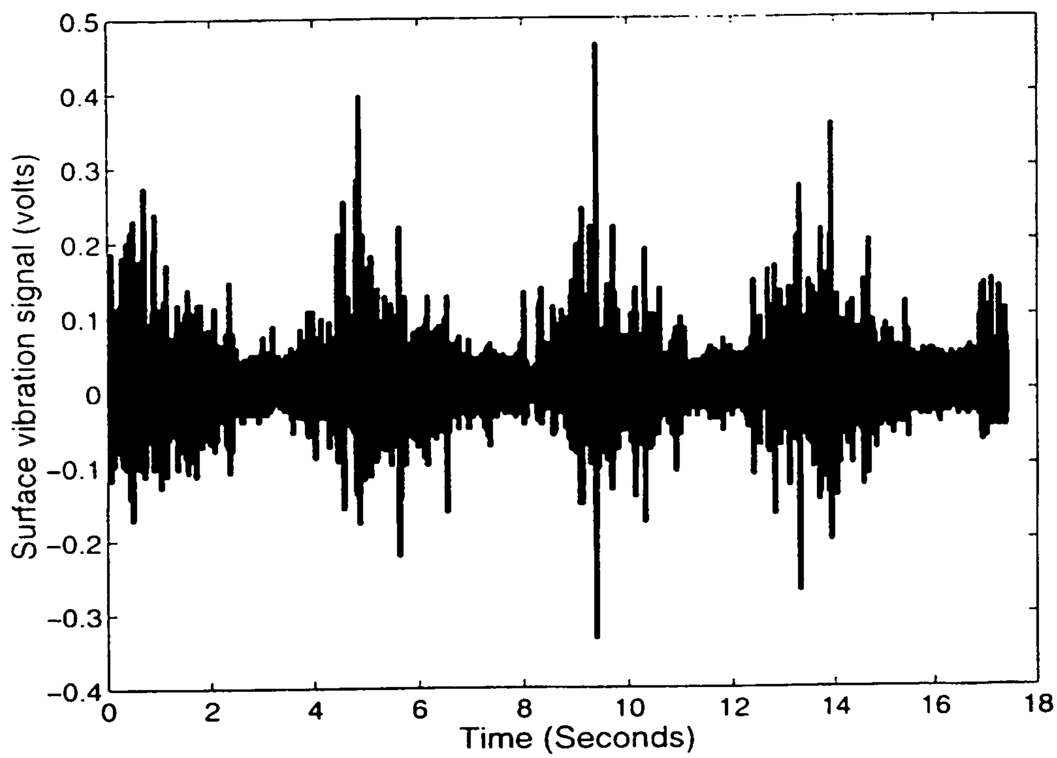

Accelerometer with radio transmitter
Proximity Switch
SAG Mill
Solar panel
Radio Receiver
Terminal Block
Laptop equipped with DAQCard/LabView

FIGURE 2



Surface vibration signal (volts)
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
0
2
4
6
8
10
12
14
16
18
Time (Seconds)

FIGURE 3a

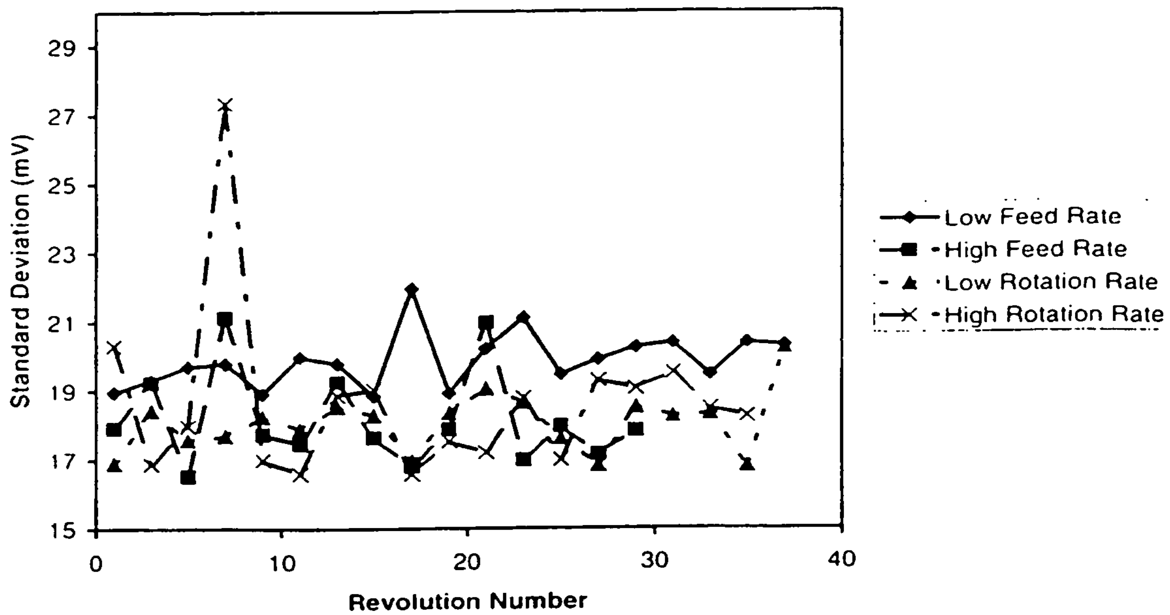
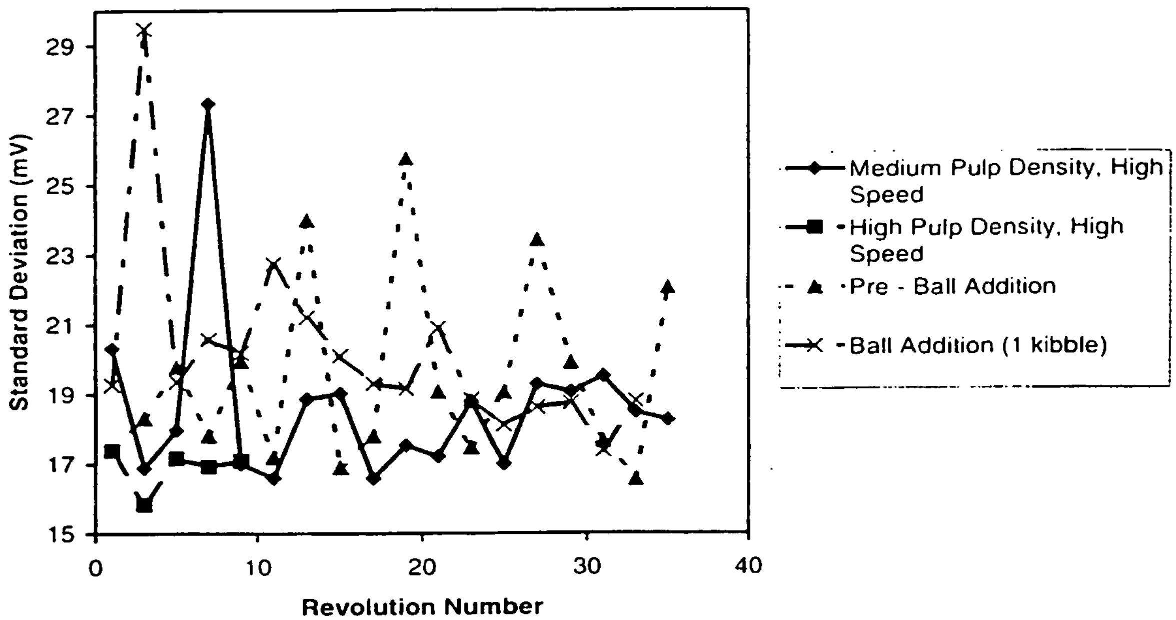

29
27
25
23
21
19
17
15
Standard Deviation (mV)
0
10
20
30
40
Revolution Number
Low Feed Rate
High Feed Rate
Low Rotation Rate
High Rotation Rate

FIGURE 3b



Standard Deviation (mV)
29
27
25
23
21
19
17
15
0
10
20
30
40
Revolution Number
Medium Pulp Density, High Speed
High Pulp Density, High Speed
Pre - Ball Addition
Ball Addition (1 kibble)

FIGURE 3c

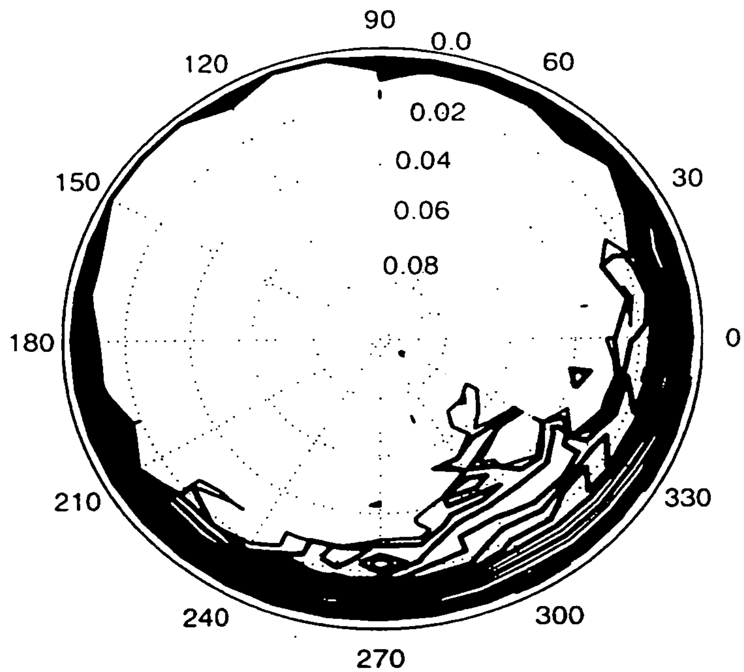


FIGURE 4a

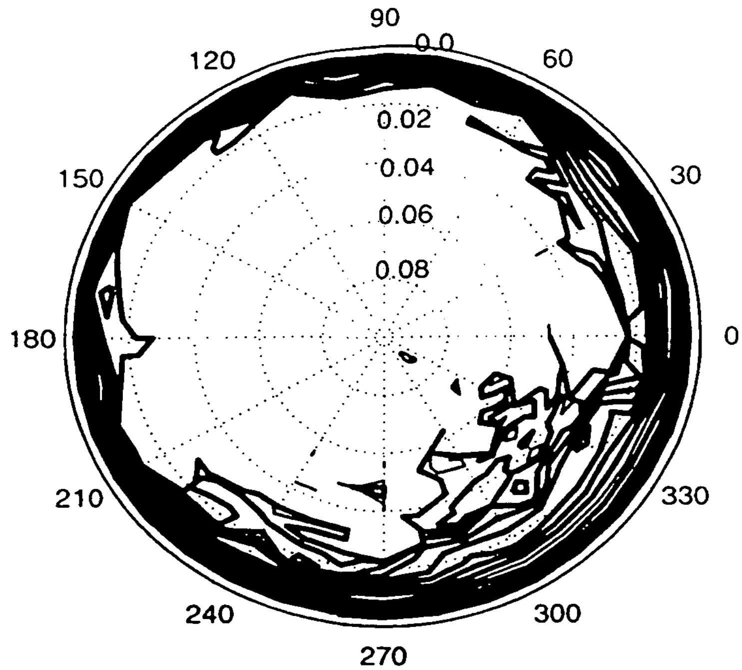


FIGURE 4b

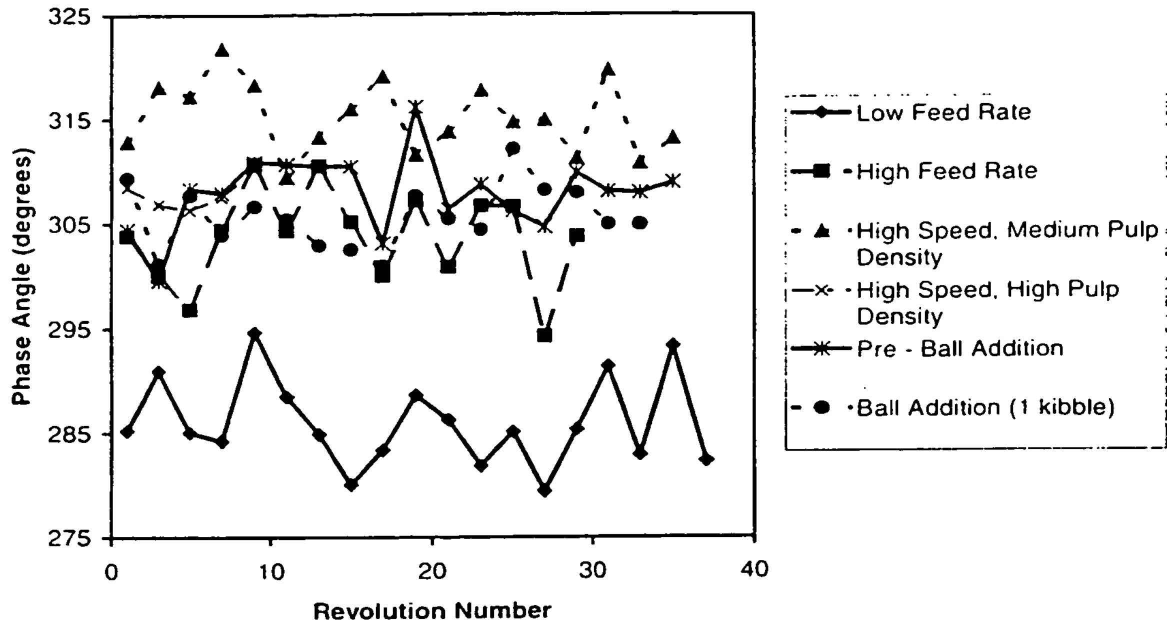

325
315
305
295
285
275
Phase Angle (degrees)
0
10
20
30
40
Revolution Number
Low Feed Rate
High Feed Rate
High Speed, Medium Pulp Density
High Speed, High Pulp Density
Pre - Ball Addition
Ball Addition (1 kibble)

FIGURE 4c

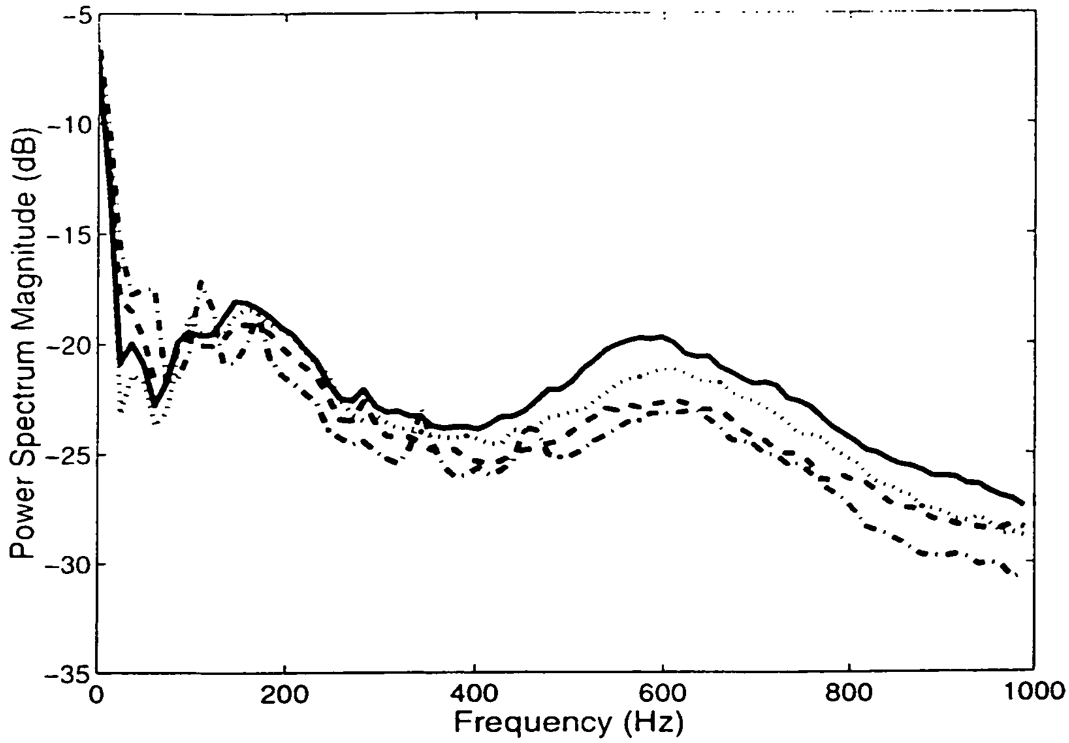

Power Spectrum Magnitude (dB)
-5
-10
-15
-20
-25
-30
-35
0
200
400
600
800
1000
Frequency (Hz)

FIGURE 5

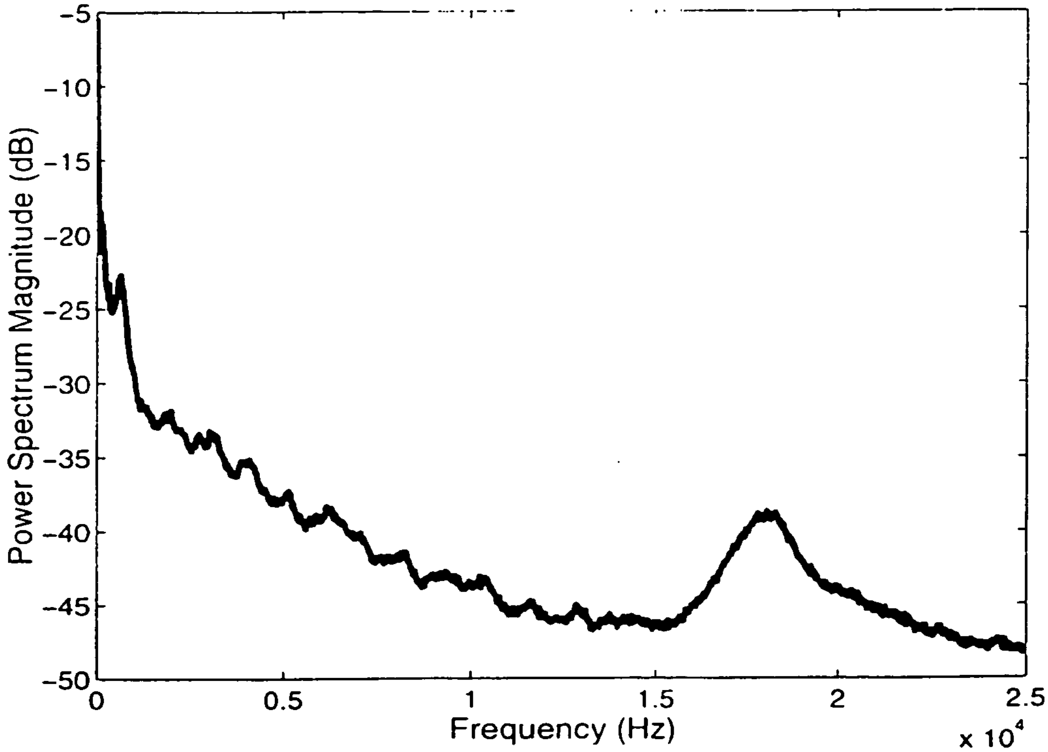

Power Spectrum Magnitude (dB)
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
0.5
1
1.5
2
2.5
Frequency (Hz)
x 10^4

FIGURE 6

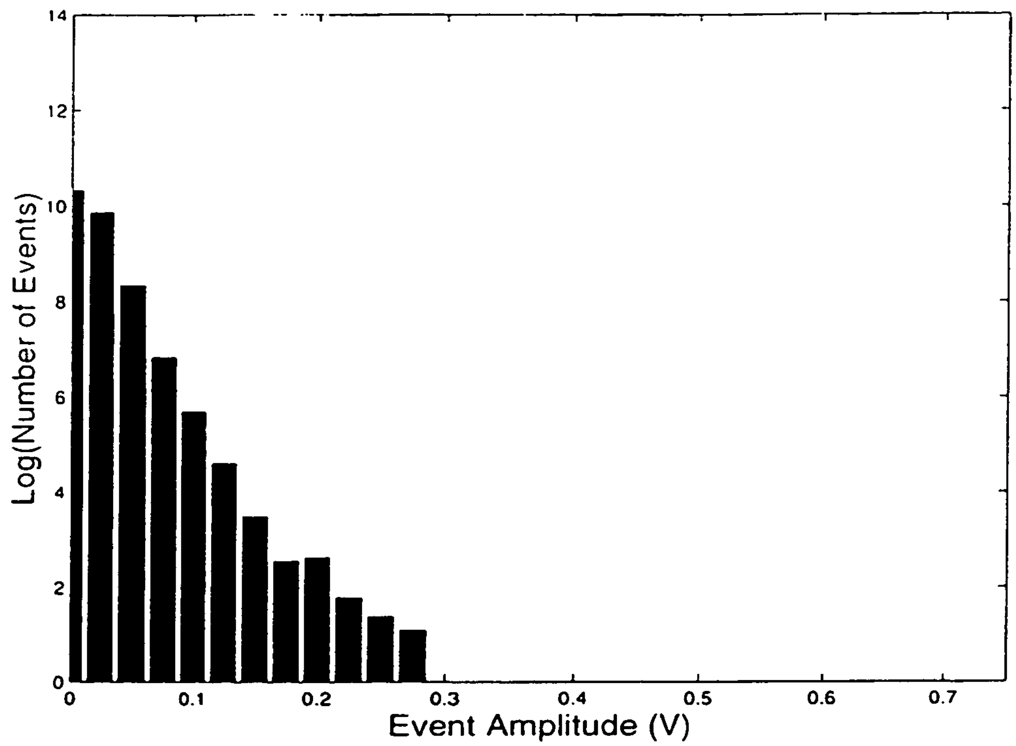

14
12
10
8
6
4
2
0
Log(Number of Events)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Event Amplitude (V)

FIGURE 7a

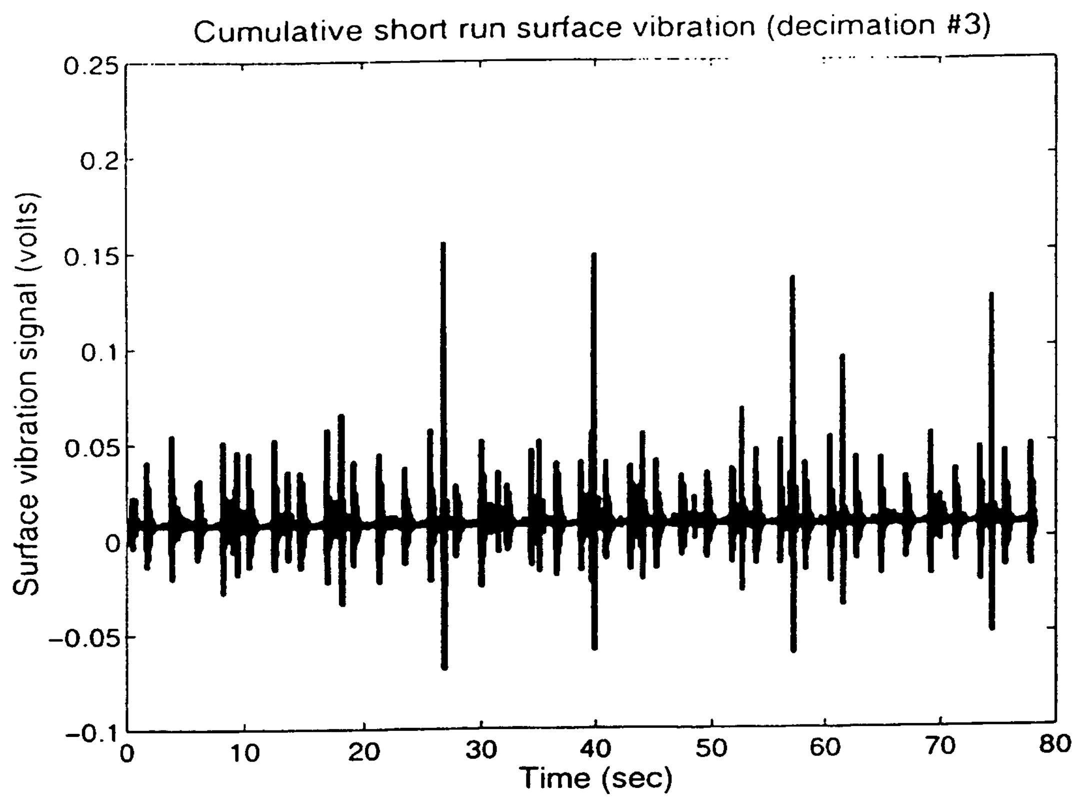

Cumulative short run surface vibration (decimation #3)
Surface vibration signal (volts)
Time (sec)
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
0
10
20
30
40
50
60
70
80

FIGURE 7b

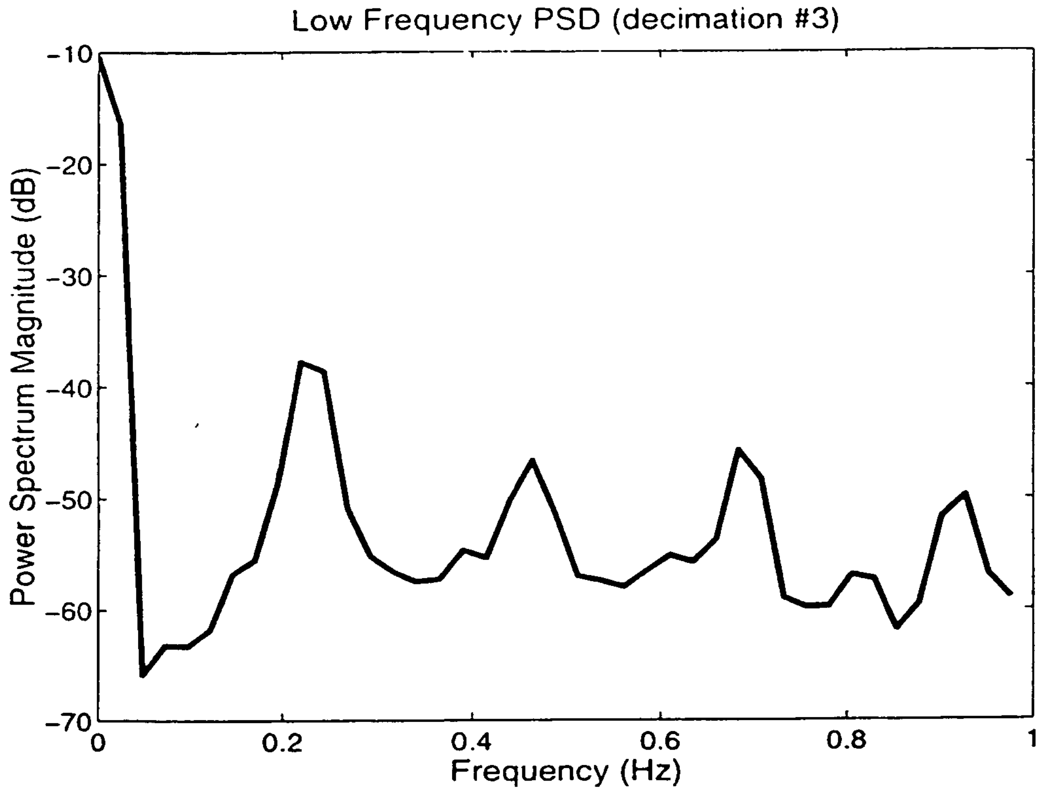

Low Frequency PSD (decimation #3)
Power Spectrum Magnitude (dB)
-10
-20
-30
-40
-50
-60
-70
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

FIGURE 7c

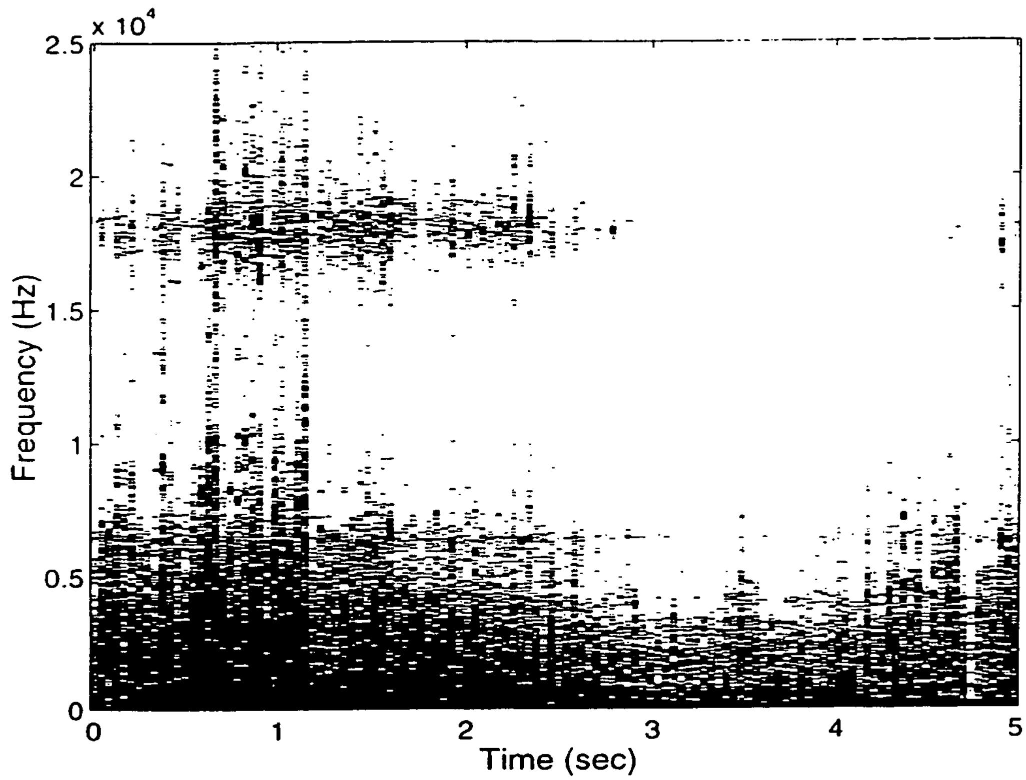


FIGURE 7d

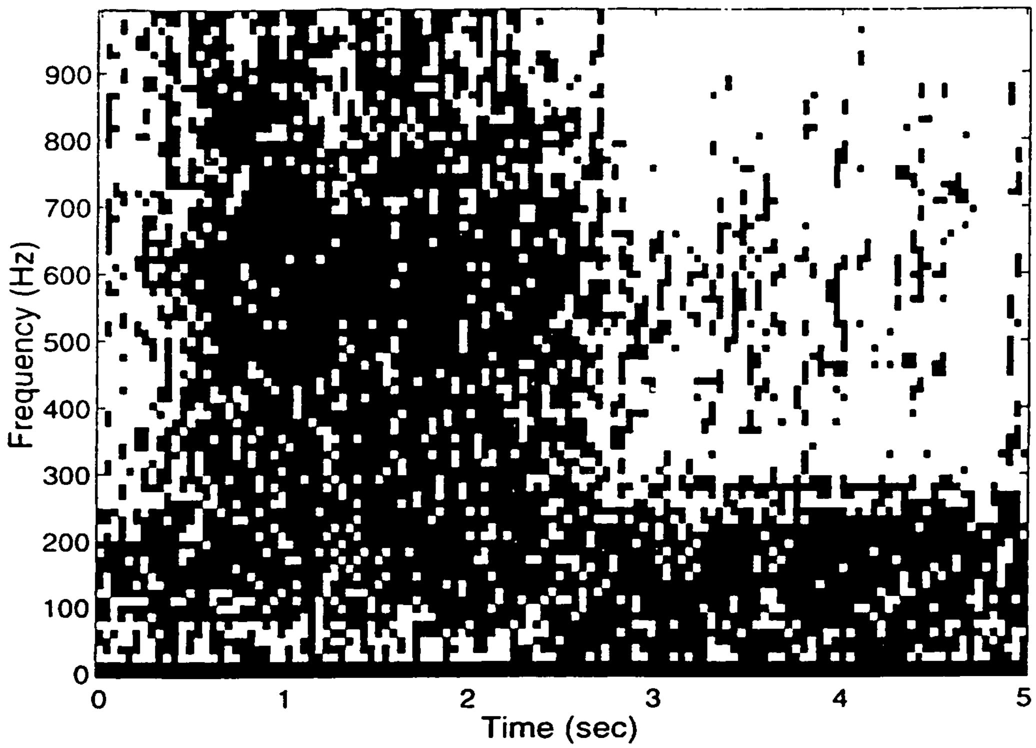

Frequency (Hz)
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
Time (sec)

FIGURE 7e

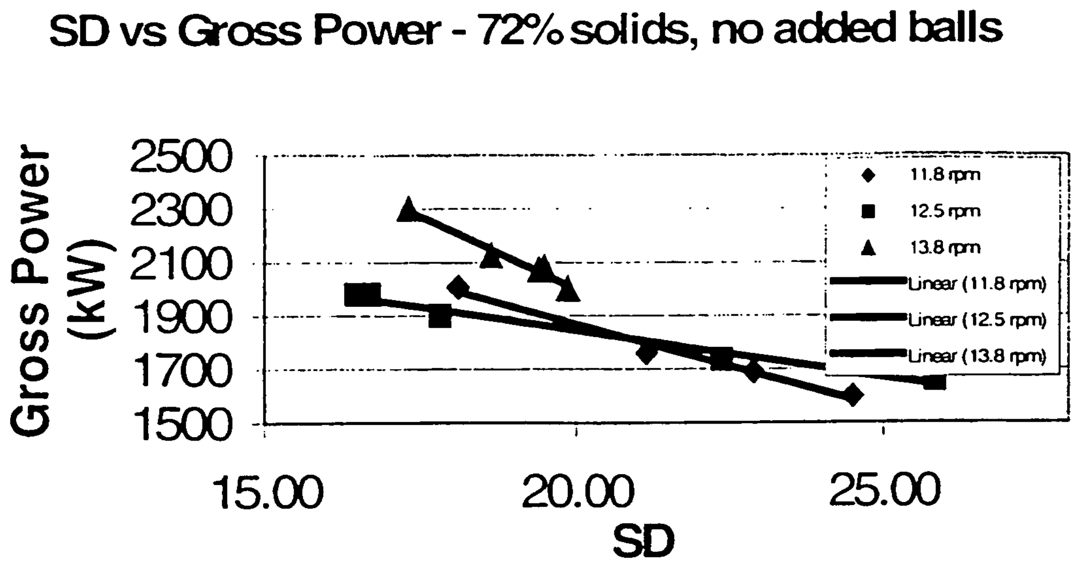

SD vs Gross Power - 72% solids, no added balls
Gross Power (kW)
2500
2300
2100
1900
1700
1500
15.00
20.00
25.00
SD
11.8 rpm
12.5 rpm
13.8 rpm
Linear (11.8 rpm)
Linear (12.5 rpm)
Linear (13.8 rpm)

FIGURE 8

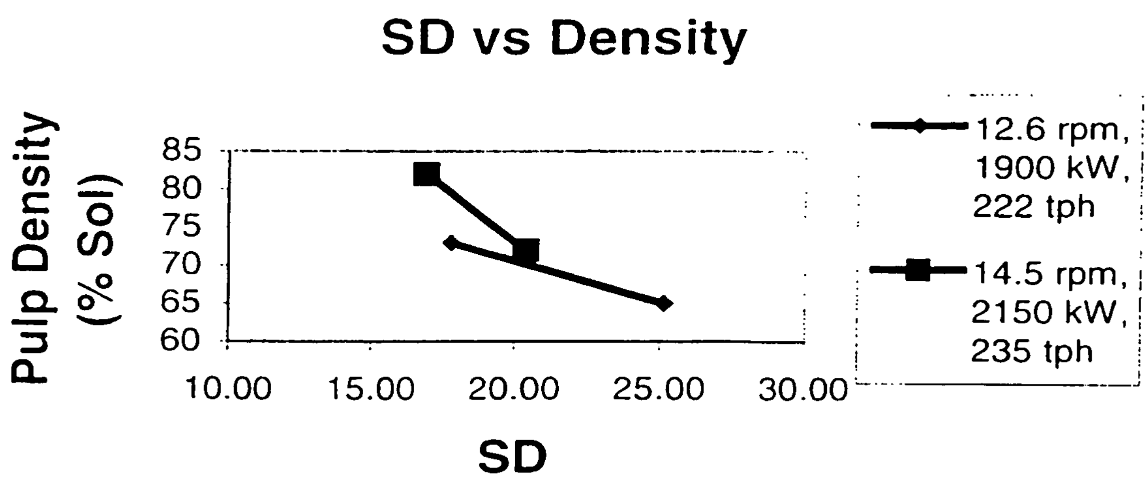

SD vs Density
Pulp Density (% Sol)
85
80
75
70
65
60
10.00
15.00
20.00
25.00
30.00
SD
12.6 rpm, 1900 kW, 222 tph
14.5 rpm, 2150 kW, 235 tph

FIGURE 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/00821

A.	CLASSIFICATION OF SUBJECT MATTER
Int Cl[7]:	B02C 025/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B02C 025/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: ACOUSTIC; CRUSH; GRIND; PORTIC, SOUND, VIBRAT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3690570 A (ROOT WILLIAM EDWARD) 12 December 1972 entire document	1-21
X	DE 4215455 A (GOLDER FRANCE DE) 18 November 1993 entire document	1-21
X	Derwent Abstract Accession No. K.1137E/30, Class P41, SU 869 809 A (KAZA POLY) 7 October 1981	1-21

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" Document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 August 2000	21 AUG 2000

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/00821

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent Abstract Accession No. 85-235616/38, Class P41, SU 1146084 A (KRIV ORE MINING) 23 March 1985	1-21
X	Derwent Abstract Accession No. D5692C/16, Class P41, SU 679243 A (AS KAZA METAL ENRIC) 15 August 1979	1-12, 18-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/00821

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member
US	3 690 570	AU 31786/71

END OF ANNEX